What is claimed is:

1. A substrate-holding device for holding a substrate while a fabrication process is being performed on the substrate, the substrate-holding device comprising:

a wafer-chuck body defining an adhesion surface and comprising an electrostatic electrode, the adhesion surface being configured to contact a downstream-facing surface of a substrate being held by the substrate-holding device by an electrostatic force generated by the electrode;

the adhesion surface defining a channel configured, whenever the substrate is adhered to the adhesion surface by the electrostatic force, to provide a conduit for a heat-transfer gas that, when in the channel, contacts and removes heat from the downstream-facing surface of the substrate;

a gas-supply conduit configured to controllably conduct the heat-transfer gas from a source to the channel;

a gas-evacuation conduit configured to controllably conduct the heat-transfer gas from the channel; and

a controller configured to (i) cause the heat-transfer gas to flow through the channel from the gas-supply conduit during a predetermined time period when the sensitive substrate is being held on the adhesion surface, (ii) at a first predetermined time instant, commence execution of the fabrication process on the substrate being held on the adhesion surface, and (iii) at a second predetermined time instant relative to the fabrication process, commence evacuating the heat-transfer gas from the channel.

2. The substrate-holding device of claim 1, wherein the controller is further configured to determine, in advance of executing the fabrication process, an expected length of an evacuation time period required to evacuate the heat-transfer gas from the channel, and to set the second predetermined time instant based on the determined expected length of the evacuation time period.

3. The substrate-holding device of claim 2, wherein the controller is further configured to determine the second predetermined time instant as occurring before commencing an exchange, on the adhesion surface, of a new substrate for an already processed substrate.

4. The substrate-holding device of claim 1, wherein the controller is further configured to establish the second predetermined time instant as occurring at an instant when the fabrication process executed on the substrate on the adhesion surface is at least 80% complete.

5. The substrate-holding device of claim 1, wherein:

the heat-transfer gas is helium; and

the controller is further configured to establish a target pressure of the heat-transfer gas in the channel of no greater than 2.7 kPa (20 Torr).

6. The substrate-holding device of claim 1, wherein the fabrication process is an exposure process.

7. A substrate-processing apparatus, comprising the substrate-holding device of claim 1.

8. A microlithography apparatus, comprising:

an exposure-optical system situated and configured to form an image, on a sensitive substrate, of a pattern using an energy beam;

a wafer chuck comprising an adhesion surface defining a channel, the wafer chuck being situated relative to the exposure-optical system and configured to hold, as the sensitive substrate is being exposed by the energy beam, a downstream-facing surface of the sensitive substrate in contact with the adhesion surface;

a gas-supply conduit configured to controllably conduct a heat-transfer gas from a source to the channel as the sensitive substrate is being held on the adhesion

surface, so as to cause the heat-transfer gas to flow through the channel and contact the downstream-facing surface;

a gas-evacuation conduit configured to controllably conduct the heat-transfer gas from the channel; and

a controller configured to (i) cause the heat-transfer gas to flow through the channel from the gas-supply conduit during a predetermined time period when the sensitive substrate is being held on the adhesion surface, (ii) at a first predetermined time instant, commence exposure of the sensitive substrate being held on the adhesion surface, and (iii) at a second predetermined time instant relative to the exposure, commence evacuating the heat-transfer gas from the channel.

9. The microlithography apparatus of claim 8, further comprising a vacuum chamber enclosing and providing a subatmospheric-pressure environment for the exposure-optical system and the wafer chuck.

10. The microlithography apparatus of claim 8, wherein the controller is further configured to determine, in advance of the exposure, an expected length of an evacuation time period required to evacuate the heat-transfer gas from the channel, and to set the second predetermined time instant based on the determined expected length of the evacuation time period.

11. The microlithography apparatus of claim 10, wherein the controller is further configured to determine the second predetermined time instant as occurring before commencing an exchange, on the wafer chuck, of a new substrate for an already-exposed substrate.

12. The microlithography apparatus of claim 8, wherein the controller is further configured to establish the second predetermined time instant as occurring at an instant when microlithographic exposure of the substrate on the wafer chuck is at least 80% complete.

13. The microlithography apparatus of claim 8, wherein:

the heat-transfer gas is helium; and

the controller is further configured to establish a target pressure of the heat-transfer gas in the channel of no greater than 2.7 kPa (20 Torr).

14. In a method for microlithographically exposing a pattern onto a sensitive substrate using an energy beam passing through a projection-optical system that forms an image of the pattern on the sensitive substrate, a method for reducing exposure-induced thermal deformation of the substrate, comprising:

providing a wafer chuck comprising an adhesion surface defining a channel, the channel being enclosable by a downstream-facing surface of a substrate being held on the adhesion surface;

mounting a sensitive substrate to the adhesion surface such that the downstream-facing surface of the substrate contacts the adhesion surface and encloses the channel;

introducing a heat-transfer gas into the channel such that the heat-transfer gas flowing through the channel contacts the downstream-facing surface of the substrate;

commencing exposure of the sensitive substrate mounted to the wafer chuck;

determining and setting an appropriate time instant, during the exposure, in which to commence evacuation of the heat-transfer gas from the channel in preparation for wafer-exchange; and

at the set time instant, commencing evacuation of the heat-transfer gas from the channel.

15. A wafer chuck for holding a substrate as a process is being performed on the sensitive substrate, the wafer chuck comprising:

an adhesion surface configured to contact a downstream-facing surface of the substrate whenever the substrate is mounted to the wafer chuck, the adhesion surface defining a channel that is enclosed whenever a sensitive substrate is mounted to the wafer chuck;

an electrode situated and configured to attract the sensitive substrate by electrostatic attraction such that the substrate is held on the wafer chuck with the downstream-facing surface contacting the adhesion surface, thereby enclosing the channel;

a heat-transfer-gas (HTG)-inlet port situated and configured to introduce a heat-transfer gas into the channel to contact with the downstream-facing surface of the substrate mounted to the adhesion surface;

a gas-evacuation port situated and configured to allow evacuation of heat-transfer gas from the channel; and

a valve mounted to the wafer chuck, the valve being configured to open and close at least one of the inlet port and the evacuation port.

16. The wafer chuck of claim 15, wherein the process is an exposure process.

17. The wafer chuck of claim 15, further comprising a controller connected to the valve and configured to open and close the valve as required to controllably cause heat-transfer gas to flow through the channel and to stop flow of heat-transfer gas through the channel.

18. A substrate-processing apparatus, comprising the wafer chuck of claim 15.

19. In a microlithography apparatus for exposing a pattern onto a sensitive substrate, a device for holding the sensitive substrate as the pattern is being exposed onto the sensitive substrate, the substrate-holding device comprising:

a movable wafer stage; and

a wafer chuck mounted to the wafer stage, the wafer chuck comprising (a) an adhesion surface configured to contact a downstream-facing surface of the substrate whenever the substrate is mounted to the wafer chuck, the adhesion surface defining a channel that is enclosed whenever a sensitive substrate is mounted to the wafer

chuck; (b) a heat-transfer-gas inlet port situated and configured to introduce a heat-transfer gas into the channel to contact the downstream-facing surface of the substrate mounted to the adhesion surface; (c) a heat-transfer-gas evacuation port situated and configured to allow evacuation of heat-transfer gas from the channel; and (d) a valve mounted to the wafer chuck, the valve being configured to open and close at least one of the inlet port and the evacuation port.

20. A wafer-processing apparatus, comprising:

a vacuum chamber configured to be evacuated so as to reduce a pressure inside the vacuum chamber;

a movable wafer stage situated inside the vacuum chamber; and

a wafer chuck mounted to the wafer stage, the wafer chuck comprising (a) an adhesion surface configured to contact a downstream-facing surface of the substrate mounted to the wafer chuck, the adhesion surface defining a heat-transfer-gas (HTG) channel; (b) an electrode situated and configured to attract the sensitive substrate by electrostatic attraction such that the substrate is held on the wafer chuck with the downstream-facing surface contacting the adhesion surface and enclosing the HTG channel; (c) an HTG-inlet port situated and configured to introduce a heat-transfer gas into the channel to contact with the downstream-facing surface of the substrate mounted to the adhesion surface; (d) a gas-evacuation port situated and configured to allow evacuation of gas from the channel; and (e) a first valve mounted to the wafer chuck, the valve being configured to open and close at least one of the HTG-inlet port and the gas-evacuation port.

21. The apparatus of claim 20, wherein the first valve is configured to open and close the HTG-inlet port, the apparatus further comprising an HTG source connected via an HTG-supply conduit to the HTG-inlet port.

22. The apparatus of claim 21, further comprising an exhaust pump connected to the HTG-supply conduit, the exhaust pump being configured to reduce a pressure in the HTG-supply conduit.

23. The apparatus of claim 22, further comprising a pressure sensor connected to the HTG-supply conduit, the pressure sensor being configured to measure the pressure in the HTG-supply conduit.

24. The apparatus of claim 22, further comprising a controller connected to the first valve, the exhaust pump, and the pressure sensor, the controller being configured to controllably actuate the first valve to introduce the heat-transfer gas into the channel when needed to remove heat from the substrate, and to actuate the exhaust pump to draw the heat-transfer gas from the channel in anticipation of substrate-exchange.

25. The apparatus of claim 21, further comprising a pressure sensor connected to the HTG-supply conduit, the pressure sensor being configured to measure a pressure in the HTG-supply conduit.

26. The apparatus of claim 21, wherein the first valve is associated with the HTG-inlet port, the wafer chuck further comprising a second valve associated with the gas-evacuation port.

27. The apparatus of claim 26, further comprising:

a gas-evacuation conduit connected to the gas-evacuation port; and

a controller connected to the first and second valves, the controller being configured to close the second valve after supplying heat-transfer gas through the HTG-inlet port to the channel and, while processing the substrate, reducing a pressure in the gas-evacuation conduit downstream of the gas-evacuation port.

28. A microlithography apparatus, comprising:

a projection-optical system situated and configured to form an image, carried by an energy beam, on a sensitive substrate;

a wafer chamber situated relative to the projection-optical system and configured to maintain the sensitive substrate at a subatmospheric pressure as the image is being formed on the sensitive substrate by the energy beam;

a movable wafer stage situated inside the wafer chamber;

a wafer chuck mounted on the wafer stage, the wafer chuck comprising an adhesion surface and being configured to attract the sensitive substrate with electrostatic force, thereby causing a downstream-facing surface of the substrate to adhere to the adhesion surface, the adhesion surface defining a heat-transfer-gas (HTG) channel configured such that a heat-transfer gas passing through the HTG channel contacts the downstream-facing surface of the substrate on the adhesion surface;

an HTG-supply system connected via an HTG-inlet valve to the HTG channel and configured to introduce the heat-transfer gas from an HTG supply into the channel;

a gas-evacuation system connected via a gas-evacuation valve to the HTG channel and configured to draw the heat-transfer gas from the channel; and

wherein at least one of the HTG-inlet valve and gas-evacuation valve is mounted on the wafer stage or wafer chuck.

29. The apparatus of claim 28, wherein the HTG-supply system comprises:

an HTG-inlet port connecting the HTG-inlet valve to the channel; and

an HTG-supply conduit connecting the HTG supply to the HTG-inlet valve.

30. The apparatus of claim 29, further comprising an exhaust pump connected to the HTG-supply conduit, the exhaust pump being configured to reduce a pressure in the HTG-supply conduit.

31. The apparatus of claim 30, further comprising a pressure sensor connected to the HTG-supply conduit, the pressure sensor being configured to measure the pressure in the HTG-supply conduit.

32. The apparatus of claim 31, wherein the gas-evacuation system further comprises:

a gas-evacuation conduit connected to the gas-evacuation valve; and

a controller connected to the HTG-inlet valve and gas-evacuation valve, the controller being configured to close the gas-evacuation valve after supplying heat-transfer gas through the HTG-inlet port to the channel and, while exposing the sensitive substrate, reducing a pressure in the gas-evacuation conduit downstream of the gas-evacuation valve.

33. In a method for performing a process on a substrate, a method for holding the substrate, comprising:

(a) providing an electrostatic wafer chuck comprising an adhesion surface defining a heat-transfer gas channel to which heat-transfer gas is supplied through a heat-transfer-gas (HTG)-inlet valve and HTG-inlet conduit connecting channel to an HTG supply, and from which gas is evacuated through a gas-evacuation valve and a gas-evacuation conduit;

(b) electrostatically attaching the substrate to the adhesion surface;

(c) at time of performing the process on the substrate attached to the adhesion surface, opening the gas-evacuation valve and the HTG-inlet valve to supply heat-transfer gas to the channel; and

(d) while performing the process on the substrate attached to the adhesion surface but after supplying the heat-transfer gas for a predetermined length of time, closing the gas-evacuation valve and applying a vacuum in the gas-evacuation conduit downstream of the gas-evacuation valve.

34. The method of claim 33, further comprising the steps, before step (b), of:

mounting the wafer chuck on a wafer stage; and

mounting at least one of the HTG-inlet valve and gas-evacuation valve on the wafer stage or wafer chuck;

35. The method of claim 33, further comprising the step, after step (d), of closing the HTG-inlet valve and opening the gas-evacuation valve, with the vacuum in the gas-evacuation conduit, so as to evacuate the channel.

36. The method of claim 35, further comprising the step, after evacuating the channel, of removing the processed substrate from the adhesion surface and exchanging the processed substrate for an unprocessed substrate.

37. The method of claim 33, wherein the process is an exposure process.

38. A substrate-holding device, comprising:

a wafer chuck comprising an adhesion surface and a heat-transfer-gas (HTG) channel;

an HTG-supply system connected to the channel and configured to supply a heat-transfer gas to the channel; and

a cold trap connected to the HTG-supply system such that heat-transfer gas intended to enter the channel passes through the cold trap before entering the channel, the cold trap being configured to remove impurities from the heat-transfer gas as the gas passes through the cold trap.

39. The substrate-holding device of claim 38, wherein the cold trap further comprises:

an adsorbent for collecting the impurities;

a vessel configured to contain a cooling substance at a temperature sufficient to at least liquefy impurities in the heat-transfer gas so that the impurities can be adsorb onto the adsorbent; and

an exhaust system connected to the cold trap, the exhaust system comprising an exhaust duct, an exhaust valve, and an exhaust pump, the exhaust valve and exhaust pump being controllably operable to isolate the cold trap from the channel and remove the adsorbed impurities from the adsorbent, respectively.

40. The substrate-holding device of claim 39, further comprising a recirculation conduit configured to recover heat-transfer gas passing through the channel and to direct the recovered heat-transfer gas to a location upstream of the cold trap so as to pass through the cold trap to the channel.

41. The substrate-holding device of claim 40, further comprising:

a bypass valve connected to the recirculation conduit;

an HTG-inlet valve connected to the HTG-supply system; and

a controller connected to the bypass valve, the HTG-inlet valve, the exhaust valve, and the exhaust pump, the controller being configured to operate the HTG-inlet valve relative to the exhaust pump so as to supply heat-transfer gas to the HTG channel, to operate the exhaust valve and exhaust pump relative to the HTG-inlet valve to remove heat-transfer gas from the HTG channel, and to operate the bypass valve to recirculate the heat-transfer gas.

42. A substrate-processing apparatus, comprising the substrate-holding device of claim 38.

43. A microelectronic-device fabrication process, comprising the steps of:

(a) preparing a wafer;

(b) processing the wafer; and

(c) assembling devices on the wafer formed during steps (a) and (b), wherein step (b) comprises the steps of (i) applying a resist to the wafer; (ii) exposing the resist; and (iii) developing the resist; and step (ii) comprises providing a charged-particle-beam (CPB) microlithography apparatus as recited in claim 7; and using the CPB microlithography apparatus to expose the resist with the pattern defined on the reticle.

44. A microelectronic device produced by the method of claim 43

45. A microelectronic-device fabrication process, comprising the steps of:

(a) preparing a wafer;

(b) processing the wafer; and

(c) assembling devices on the wafer formed during steps (a) and (b), wherein step (b) comprises the steps of (i) applying a resist to the wafer; (ii) exposing the resist; and (iii) developing the resist; and step (ii) comprises providing a charged-particle-beam (CPB) microlithography apparatus as recited in claim 28; and using the CPB microlithography apparatus to expose the resist with the pattern defined on the reticle.

46. A microelectronic device produced by the method of claim 45.